MONTANA STATE HIGHWAY DEPARTMENT

HIGHWAY PLANNING SURVEY

IN COOPERATION WITH

PUBLIC ROADS ADMINISTRATION

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# APPLICATION OF THE OREGON SOLVENCY QUOTIENT METHOD TO ESTABLISH PRIORITY IN THE SELECTION OF ROUTES BETWEEN BOULDER AND WHITEHALL (HILL ROAD) AND BOULDER AND CARDWELL (VALLEY ROAD) IN JEFFERSON COUNTY



January 1946

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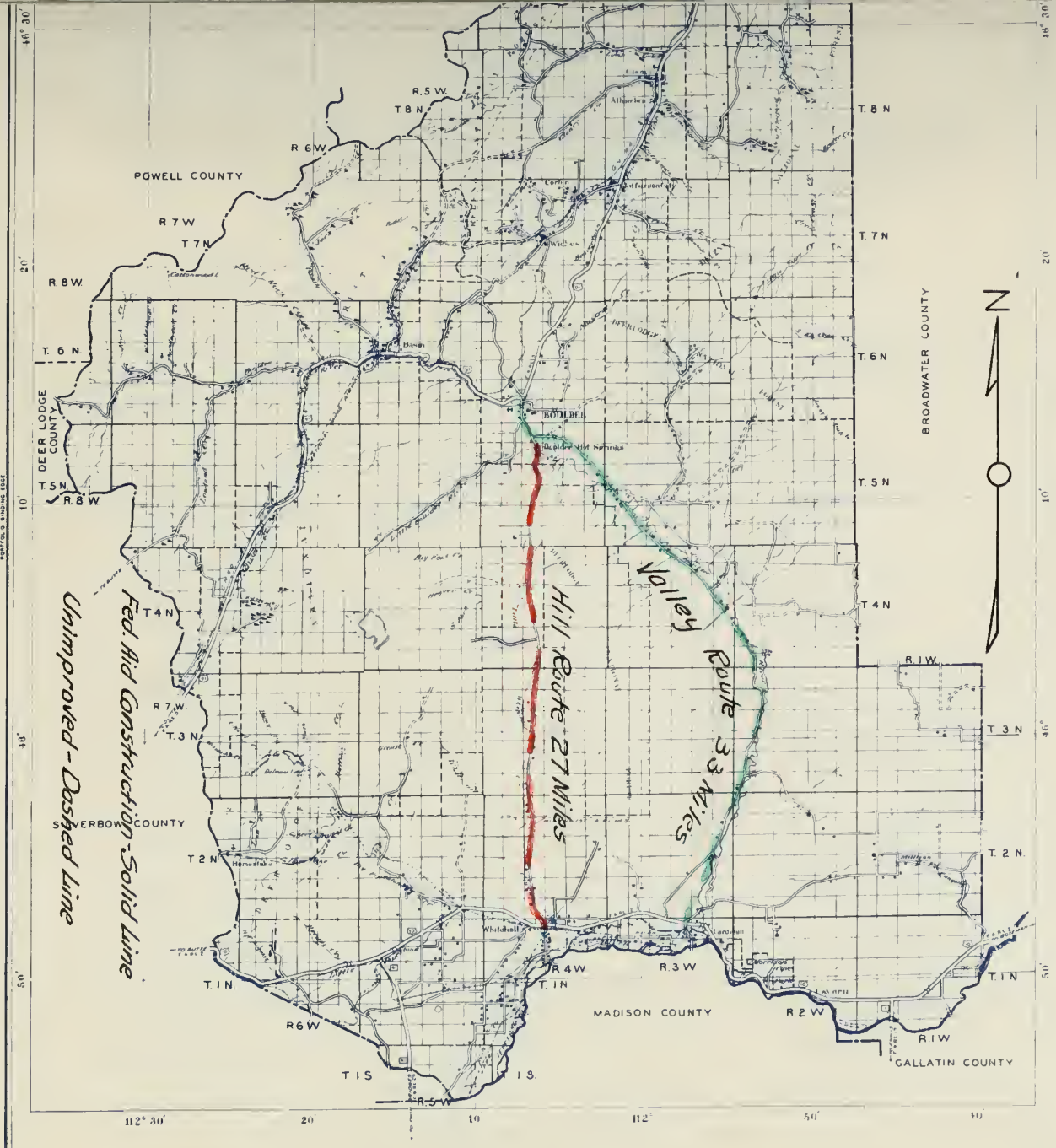


BASE MAP

# JEFFERSON COUNTY
# MONTANA

PREPARED BY THE
MONTANA STATE HIGHWAY DEPARTMENT
IN COOPERATION WITH THE
U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
DATA OBTAINED FROM
STATE-WIDE HIGHWAY PLANNING SURVEY

1936

POLYCONIC PROJECTION
NORTH AMERICAN DATUM

PRIMARY SYSTEM REVISED JULY 1937

Montana State Highway Department
Traffic and Planning Section
Public Roads Administration
Basic Design Categories
Table No. 1

| Standard | Average Daily Traffic | Classification | Max. Grade | Max. Curvature (Degree) | Sight Distance: Non Passing: Horiz. Curvature (Degree) | Sight Distance: Non Passing: Vertical Curvature (Algebraic Difference) | Sight Distance: Passing: Feet | Sight Distance: Passing: Feet | Shoulder Width | Width of Road Bed at Grade | Width of Surfacing | Minimum Type of Surfacing | Minimum Base Course |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0-200 | 20 M 40 | 7 | 14 | 14 | | 280 | 800 | 3 | 24 | 18 | Under 1" Oil | 5" |
| 1 | 201-400 | 50 M 40 | 7 | 14 | 14 | | 290 | 800 | 4 | 28 | 20 | 2" Oil | 6" |
| 2 | 401-800 | 100 M 40 | 7 | 14 | 14 | | 310 | 1100 | 5 | 32 | 22 | 2½" Oil | 8" |
| 3 | 801-1800 | 200 M 40 | 7 | 14 | 14 | | 320 | 1100 | 6 | 34 | 22 | 2½" Oil | 8" |
| 4 | 1801-3500 | 300 M 40 | 7 | 14 | 14 | | 330 | 1100 | 8 | 38 | 22 | 2½" Oil | 8" |
| 5 | 0-200 | 20 M 60 | 6 | 6 | 6 | | 460 | 1700 | 3 | 26 | 20 | Under 1" Oil | 5" |
| 6 | 201-400 | 50 M 60 | 6 | 6 | 6 | | 460 | 1700 | 4 | 30 | 22 | 2" Oil | 6" |
| 7 | 401-800 | 100 M 60 | 6 | 6 | 6 | | 470 | 2100 | 5 | 32 | 22 | 2½" Oil | 8" |
| 8 | 801-1800 | 200 M 60 | 6 | 6 | 6 | | 480 | 2100 | 6 | 34 | 22 | 2½" Oil | 8" |
| 9 | 1801-3500 | 300 M 60 | 6 | 6 | 6 | | 500 | 2100 | 8 | 38 | 22 | 2½" Oil | 8" |

SEE TABLE NO. 2.

Note: Roads having over 3500 vehicles per day require special design.

TABLE NO. 2

Table giving length of vertical curve required for various Non - passing sight distances

December 18, 1943

| Algebraic Difference between grades for convex curvature. | Length of vertical curve for a Non-passing sight distance of: 280 feet | Length of vertical curve for a Non-passing sight distance of: 290 feet | Length of vertical curve for a Non-passing sight distance of: 310 feet | Length of vertical curve for a Non-passing sight distance of: 320 feet | Length of vertical curve for a Non-passing sight distance of: 330 feet | Length of vertical curve for a Non-passing sight distance of: 460 feet | Length of vertical curve for a Non-passing sight distance of: 470 feet | Length of vertical curve for a Non-passing sight distance of: 480 feet | Length of vertical curve for a Non-passing sight distance of: 500 feet |
|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 96 | 103 | 117 | 125 | 133 | 258 | 269 | 281 | 305 |
| 2.00 | 191 | 205 | 234 | 250 | 266 | 516 | 539 | 562 | 610 |
| 3.00 | 287 | 308 | 352 | 375 | 398 | 774 | 808 | 843 | 915 |
| 4.00 | 382 | 410 | 469 | 500 | 531 | 1032 | 1078 | 1124 | 1220 |
| 5.00 | 478 | 513 | 586 | 624 | 664 | 1290 | 1347 | 1405 | 1524 |
| 6.00 | 574 | 615 | 703 | 749 | 797 | 1548 | 1616 | 1686 | 1829 |
| 7.00 | 669 | 718 | 820 | 874 | 930 | 1806 | 1886 | 1967 | 2134 |
| 8.00 | 765 | 820 | 938 | 999 | 1062 | 2064 | 2155 | 2248 | 2439 |
| 9.00 | 860 | 923 | 1055 | 1124 | 1195 | 2322 | 2425 | 2529 | 2744 |
| 10.00 | 956 | 1026 | 1172 | 1249 | 1328 | 2581 | 2694 | 2810 | 3049 |
| 11.00 | 1052 | 1128 | 1289 | 1374 | 1461 | 2839 | 2963 | 3091 | 3354 |
| 12.00 | 1147 | 1231 | 1406 | 1499 | 1594 | 3097 | 3233 | 3372 | 3659 |
| 13.00 | 1243 | 1333 | 1524 | 1623 | 1726 | 3355 | 3502 | 3653 | 3963 |
| 14.00 | 1339 | 1436 | 1641 | 1748 | 1859 | 3613 | 3771 | 3934 | 4268 |

MONTANA HIGHWAY PLANNING SURVEY

GUIDES FOR ESTIMATING 1960 TRAFFIC

| | | Applies to: |
|---|---|---|
| 1. | 100% = 1941 traffic. | |
| 2. | 110% to 125% = Traffic if route is unimproved at present time but expected to be improved by 1960. | F.A., F.A.S. and Class 1, 2, & 3 Forest Highways. Applies to sparcely settled rural areas.<br><br>(Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities). |
| 3. | 125% to 150% = Traffic if route is unimproved at present time but expected to be improved by 1960. | F.A., F.A.S. and Class 1, 2, & 3 Forest Highways. Applies in checkerboard well-settled rural areas or on through-roads.<br><br>(Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities). |
| 4. | 150% to 200% = Traffic if route is unimproved at present time but expected to be improved by 1960. | F.A., F.A.S. and Class 1, 2, & 3 Forest Highways. This applies in exceptional cases such as bottlenecks and natural cutoffs. Some cases, of course, might be much more but these special conditions would require special analysis.<br><br>(Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities). |
| Note: | Date of expected improvement does not change traffic estimates for 1960. | |

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130% = expected secular growth 1941 to 1960 -- to be applied to all above conditions except traffic generated by logging activities, or other major industries.

Applies to all roads now constructed. (Without any of above increases)

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Average summer maximum traffic equals double average ADT except on predominately recreational routes where factor might be as high as 3.

Average summer maximum traffic equals average of several maximum summer days.

Maximum hour equals 10% of maximum summer ADT. (Usual public traffic), or 15 to 20% on roads used by both the public and by major logging operations or other major industries.

TABLE OF CONTENTS

APPLICATION OF THE OREGON SOLVENCY QUOTIENT METHOD TO ESTABLISH PRIORITY IN THE SELECTION OF ROUTES BETWEEN BOULDER AND WHITEHALL (HILL ROAD) AND BOULDER AND CARDWELL (VALLEY ROAD) IN JEFFERSON COUNTY

## I. SUMMARY OF FINDINGS

Herewith report as per title above using the principles of the Oregon solvency quotient method. By setting up a mathematical relationship between estimated costs on the one hand, and possible future revenues and benefits on the other, an index of desirability is established to aid in the choice of routes. Every one of the factors involved in the derivation of solvency quotients grows out of, or is influenced by, the economics of the region touching on or adjoining the route under analysis. The course of action recommended by the application of the solvency quotient method is therefore premised on a business-like procedure, and it follows, obviously, that such action will be in the greatest interest of the public. In this particular problem, the Hill Road is the better choice. Here are the results of the analysis:-

SOLVENCY RESULTS

| Quotient Descriptions | Hill Road | Valley Road |
|---|---|---|
| $Q_S$ - Annual Revenues ÷ Annual Capital Costs | 0.44 | 0.40 |
| $Q_{BN}$ - Annual Non Fuel Benefits ÷ Annual Capital Costs | 1.30 | 0.73 |
| $Q_{BF}$ - Annual Fuel Benefits ÷ Annual Capital Costs | 0.50 | 0.29 |
| $Q_S + Q_{BN} + Q_{BF}$ = Actual Solvency | 2.24 | 1.42 |
| $Q_C$ Composite Solvency $0.707 (Q_S + Q_{BN} + Q_{BF} (1-K_2K_3))$ | 1.54 | 0.98 |

These data show that in reference to costs, the Hill Road will "earn", by reason of the gas tax levy, 44% of estimated expenditures - the Valley Road will earn 41%. Non-fuel benefits (monetary value of time savings, decrease in

"wear and tear", etc.) accruing to Hill Road traffic will be 130% of the capital costs - similar benefits on the Valley Road will be 73% of the capital costs. It is readily seen that the "pull" for the Hill Road on the basis of this one quotient is almost two to one. Dropping to the Composite Solvency, which involved consideration of all the factors of system solvency and the relationship of benefits to expenditures, we find that the Hill Road has an over-all pull of approximately three to two (1.54/0.98).

These results are based on data at hand in the Montana Planning Survey, the traffic data leading to conclusions in reference to gas tax revenues originated with the 1941 traffic records and the 1936-1937 Origin-Destination studies at Dillon and Helena. Data in re mileage, rise and fall, gradient, and wearing surface are on file in the office of the Highway Planning Survey.

This analysis also assumes a situation whereby a through route is built from Dillon through Twin Bridges, thence along the Vigilante Trail to a point north of Silver Star, thence northeasterly to Whitehall. The two routes proposed for analysis remain as keys in the final link-up between Dillon and Boulder. The effect of such reasoning is to throw all benefits of distance savings, gradient savings, and rise and fall savings on these two roads. Since these values are assigned in equal measure insofar as the number of vehicles is concerned, to each of the two roads, the effect in the derivation of the solvency quotient is impartial and just.

Lacking complete economic data, the writer has developed and expanded on existing traffic records to arrive at estimates of traffic in 1960 in line with principles advanced by the Planning Survey. These principles, now accepted by traffic authorities, are as follows:-

1. Immediately on completion of a road improvement on a through route there is a 50% increase of traffic along the length of such improvement.
2. Traffic will increase 30% in twenty years as a function of population growth and the growth of motor vehicle ownership.

The first principle, it is believed, serves as a "catch all" for economic developments in the area and for a change in driving habits of the people resident along the road.

The details of the analysis are set forth in Sections II, III, and IV which follow hereinafter.

## II. ROUTE DESCRIPTIONS

The routes proposed for comparative analysis extend from Whitehall to Boulder (Hill Road) and from Cardwell to Boulder (Valley Road), the distances involved being 27 miles and 33 miles, respectively. Both routings lie in Jefferson County and, depending on future administrative action, will comprise a part or parts of the Federal Aid Secondary System. The Hill Road, beginning at a junction with US-10 in Whitehall, elevation 4,360, rises in a distance of 20 miles to an elevation of 5,730, then drops 800 feet in four miles to the Boulder Valley - the remaining 3 miles of the route traverse comparatively flat lands crossing the Boulder River at the outskirts of Boulder, elevation 4,900 to make a junction with US-91 in that town. The road as now used is kept in fairly good condition, the basic soils are gravelly in the bottom lands and leading to the crest of the hill - it is probable that this latter mentioned section will recuire some rock excavation, granite in the main. For purposes of analysis it is proposed that the Hill

Road will join with the Valley Road at a point two miles south of Boulder - the northerly section of the Valley Road has been graded and drained under a previous program for a distance of 15.5 miles. By so doing, we establish a situation whereby improvement of the Hill Road will involve 25 miles of new construction and 2 miles of gravel and base construction along with oil surfacing. There are, in general, no special conditions impinging on the construction picture of this road.

The Valley Road, beginning near Cardwell on US-10, follows the course of the Boulder River to Boulder and a junction with US-91 in that town. As brought out heretofore, 15.5 miles of the routing have been graded and drained, leaving 17.5 miles of new construction and 15.5 miles of gravel base and gravel surfacing along with oiling. That section of the road which is unimproved is not kept in as good a state of repair as the Hill Road. The road traverses gravelly bottom lands; there are no special conditions surrounding the proposed improvement of this road.

In both instances the roads serve a farming-grazing economy - the Valley Road is of immediate service to more residents living outside the incorporated limits of Whitehall and Boulder than the Hill Road, the ratio being about three to two. On the other hand, the Hill Road serves more town dwellers of Jefferson County because it lies in a direct line between Whitehall, population 818 and Boulder, population 510.

III. TRAFFIC DATA

Traffic and vocational pursuits are inter-related to a remarkable degree - given an economy which has suffered by virtue of "hard times" one will find a significant decrease in traffic volumes. Given prosperous times, one will find a significant increase in traffic. It is not claimed that there is a true dollar-for-dollar relationship in the two variables, economy and

traffic. However, the relationship is binding enough for us to say that traffic records are indicative of economic trends and that fluctuations in such records are indicative of similar rise and fall in the economic pattern of the area being studied. By so treating with the economy of the area along a given routing, we thus avoid manipulation of ponderous business and production statistics; our traffic records will suffice. It remains for us, however, to label the existing traffic and that which might develop in the future in terms of the economic function which prompts, or might prompt, such traffic.

It is a well known fact to all that the Valley Road carries "farming-grazing" traffic; there is very little traffic on the road which we can reasonably associate with other interests. On the Hill Road we have an equivalent amount of "farming-grazing" traffic along with traffic which is intent on other interests, economic and recreational. Both roads serve local traffic; a recent survey of the two routings showed that 85% of the vehicles on the Hill Road were registered in Jefferson County - the traffic on the Valley Road was 90% Jefferson County.

The analysis which follows (see section IV) is predicated on possibilities which might obtain in 1960 - but we do not know of, nor do we attempt herein to forecast, the 1960 economy of Jefferson County and the area contiguous thereto. However, we have recourse in traffic trends and patterns, which, as we have stated hereinbefore, are almost synonymous and equally effective with economic trends. The patterns and bases of traffic estimation, in other words, are liberal and comprehensive enough, we believe, to provide for any fundamental or basic change of the economy in any given area.

Aside from Jefferson County aspects of the problem we have the possibility of diversion to the routes should either one be built. For example, if the Valley Road were built it would form a link in a route

extending from Dillon to Boulder over a water grade; furthermore, it would be four miles shorter than the present traveled way, US-91 via Butte, and such through traffic would avoid traffic congestion on the streets of that municipality. On the other hand, Butte is an established community, it is a marketing center for a considerable area, it is also a place of interest to tourists and casual Montana travelers; will economic aspects so change in the future that commercial and industrial traffic will have less occasion to "call" in Butte?

The foregoing discussion is an extreme possibility; the real question is: How much commercial traffic, heavy hauling, as it were, having no interest in Butte, will take advantage of the water grade route from Dillon to Boulder and vice versa? As for tourists and pleasure drivers, how many of such category would choose to miss Butte to take advantage of a less scenic route to save distance and time? Here is another possibility: given the same conditions of improvement, would the pleasure drivers of Butte make use of the valley road in a tour to Morrison Cave via Boulder, the Valley Road, and return by way of Whitehall and the Pipestone Pass road, US-10? It is a known fact that pleasure drivers do not like to "repeat" on a road when in quest of recreation and diversion.

Now to discuss the Hill Road; if it were built, would the through Dillon-Boulder traffic use it in any great degree? It is seventeen miles shorter by way of Whitehall and the Hill Road than it is via Butte, US-91. Would there be a significant diversion of commercial traffic over the improvement? By use of the road, the diverted traffic would profit by the decreased travel distance, improved alignment, lack of city congestion, decreased rise and fall. But in what measure?

The foregoing discussion presents the possibilities inherent in the improvement of either of the two routings. The data are now assembled to draw out specific conclusions in reference to the choice of the route to be improved.

## IV. ECONOMIC ANALYSIS

### A. THE HILL ROAD, 27 MILES.

#### 1. Annual Cost Calculations.

It is assumed that this route will be built to Standard No. 1 for the reason that oil surfacing to the depth of 2" will thus be provided. (See Basic Design Categories, pages, i, ii).

It is to be noted that the estimated average daily traffic as developed hereinafter would recommend that choice. Costs would approximate those experienced in the construction of the Boulder Valley Road and the northerly end of the Vigilante Trail. These costs are presented herewith:

BASIC CONSTRUCTION COSTS

| Project | Const. Year | Length | Grading | Clear & Grub | Base & Grad | Oiling | DRAINAGE Minor Structures | DRAINAGE Major Structures | Engr | R/W |
|---|---|---|---|---|---|---|---|---|---|---|
| 9A | 1940 | 6.6 | 24,403 | 11476 | | | 19,337 | | 6453 | |
| 9A | 1940 | 0.1 | | | | | | 3,532 | 412 | |
| 9B | 1941 | 4.5 | 12,877 | | | | 7,989 | | 3009 | |
| 9C | 1941 | 4.4 | 9,595 | | | | 12,417 | | 3009 | |
| Totals | | 15.5 | 46,875 | 11476 | | | 39,743 | 3,532 | 12883 | |
| Averages | | 15.5 | 3,024 | | | | 2,564 | | 831 | |
| Averages | | 8.9 | 2,525 | | | | 2,293 | | 676 | |
| Averages | | 6.6 | 3,697 | 1739 | | | 2,930 | 535 | 1040 | |
| 281A | 1936 | 9.3 | 43,285 | | 30219 | 7782 | 8,373 | 6,845 | 9337 | 3696 |
| 281B | 1936 | 6.2 | 31,060 | | 19715 | 11682 | 28,363 | 8,906 | 14707 | 3013 |
| Totals | | 15.5 | 74,345 | | 49934 | 19464 | 36,736 | 15,751 | 24044 | 6709 |
| Averages | | 15.5 | 4,796 | | 3221 | 1256 | 2,370 | 1,016 | 1551 | 433 |

Drawing on this experience and making due allowance for possible increase in unit prices, we find reasonable costs per mile as follows:-

Whitehall to Junction with Valley Road, 25 miles

| | |
|---|---|
| Grading..... | $4,000 |
| Assuming the hill construction cost to be 1/3 more than the 1940-1941 Valley Road costs. | |
| Gravel Base & Surface..... | $3,500 |
| Assuming quantities to be less than those encountered on the Vigilante Trail but at a higher unit price. | |
| Clearing & Grubbing..... | $ 350 |
| Assuming prices to be same as for Valley Road but effective for only five miles. | |
| Oil Surfacing..... | $1,300 |
| Assuming prices similar to those for the Vigilante Trail. | |
| Minor Drainage Structures..... | $2,000 |
| Assuming less need for such structures than was manifest along the Valley Road. | |
| Major Structures..... | $1,000 |
| Assuming conditions similar to those of the Valley Road. | |
| Engineering..... | $1,000 |
| Assuming conditions analagous to the 1940-41 Valley construction. | |
| Right of Way..... | $ 250 |
| Assuming prices similar to those of the Vigilante Trail but in lesser areal dimension. | |
| Sub-Total.... | $13,400 |
| + 10% for contingencies..... | 1,340 |
| Total.... | $14,740 |

Junction to Boulder, 2 miles

| | |
|---|---|
| Gravel Base & Surface..... | $4,000 |
| Assuming a "city section" in Boulder to increase the price over that estimated for the Hill Section. | |
| Oil Surfacing..... | $1,500 |
| See above. | |
| Engineering..... | $ 300 |
| Sub-Total..... | $5,800 |
| + 10% for contingencies..... | 580 |
| Total..... | $6,380 |

Drawing on these data we find the total cost of the new construction, 25 miles, to be..... 25 x $14,740 = $368,500

The cost of the gravel surfacing and the oiling... 2 x $ 6,380 = 12,760

to render the total cost of new construction at... $381,260

To the total for the new construction it is necessary to add the 1940 costs for grading and installation of drainage structures on the last two miles of the route, this being $19,882. Assuming we were to capitalize the route in 1944, the total net cost of construction would be $401,142.

It is believed that traffic will demand or require roads of higher standard as time goes on to thus require a greater outlay on reconstruction. Interest changes should be assigned in recognition of this feature - in other words, the road "as built" should lay up a reserve to meet increased construction costs in the future. Accordingly, the Hill Road construction costs have been assigned an interest charge of 2½% to be amortized in twenty years, this time period being deemed significant of the service life of the proposed improvement.

The gross cost when interest is applied at 2½% for twenty years is $514,264 and the annual capital cost would be $25,713.

From data at hand it is reasonable to assume that maintenance costs to include administration and overhead will be approximately $250 per mile per year and that the total annual cost will be $6,750.

Total annual costs are tabulated in somewhat lesser detail on the "Annual Cost Calculations" which follows hereinafter:

## ANNUAL COST CALCULATIONS

Location of project Montana County Jefferson

Description of project Whitehall - Boulder

Highway number ____ Highway system F.A. Secondary

Length 27.0 miles Date of analysis November 1945

### CAPITAL COSTS

| Item | Net Cost | Gross Cost 1/ | Amort. Period | Annual Capital Cost |
|---|---|---|---|---|
| Rights of way, easements, etc. | $ 6,250 | $ | | $ |
| Clearing, grading, etc. | 119,622 | | | |
| Pavements and surfacing: | | | | |
| Type 483 , 25 Mi. | 120,000 | | | |
| Type 483 , 2 Mi. | 11,000 | | | |
| Structures: | | | | |
| Type Minor , 27 Mi. | 55,860 | | | |
| Type Major , 27 Mi. | 26,070 | | | |
| Other Construction items:..... | 62,340 | | | |
| Unamortized cost const..... | 401,142 | 20 yrs | @ 2½% | |
| 1. Total annual capital cost..... | | | | $ 25,713 |

### MAINTENANCE COSTS

2. Total annual maintenance cost 27 miles @ $250 $ 6,750

### OPERATION COSTS

3. Additional mileage ____ at ____ per mile $ ____

TOTAL ANNUAL COSTS (1 + 2 + 3) $ 32,463

1/ Engineering and 10% for contingencies included with "Other Construction Items".

2. Average Daily Traffic, 1960

We have traffic records as of 1941 to indicate density as follows between Whitehall and Boulder. To these data we have added 50% to allow for the usual increase on completion of an improvement and 30% to allow for the normal traffic growth.

BOULDER-WHITEHALL TRAFFIC VIA HILL ROAD

| Type | 1941 | + 50% Comp. Const. | + 30% 1960 |
|---|---|---|---|
| Local Pass. Cars | 75 | 112 | 145 |
| Foreign Pass. Cars | 1 | 2 | 3 |
| Trucks, Trailers, Etc. | 22 | 33 | 43 |
| TOTALS | 98 | 147 | 191 |

With reference to that traffic which might conceivably be diverted to the Hill Road from US-91 we have basic data deriving from an Origin-Destination study conducted in 1936-1937 at loadometer stations near Dillon and Helena. The results of the analysis at these stations corresponded close enough to allow use of the data in this analysis. The data of interest are tabulated herebelow:

DILLON LOADOMETER STATION PASSENGER CARS

| | Origin | Possible Diversion | Destination: Inter County | Intra County | Foreign |
|---|---|---|---|---|---|
| 6 | | | | | |
| AM | Outlook | 1: 0.5 | | | 0.5 |
| to | Dillon | 11: 1 | 3 | 4 | 3 |
| 2 | Helena | 1: 1 | | | |
| PM | Great Falls | 1: 1 | | | |
| | Other Towns | 11: | 4 | | 7 |
| S | Counties | 9: | 1 | 8 | |
| E | Foreign | 2: | | | 2 |
| P | Total O-D Cards | 36: 3.5 | 8 | 12 | 12.5 |
| T. | Expand to Actual | | | | |
| 30 | Count (Local) | 163: 17 | 38 | 58 | 50 |
| 1 | Expand to Actual | | | | |
| 9 | Count (Foreign) | 54: | | | 54 |
| 3 | Reduce to ADT (Local | 197: 21 | 46 | 70 | 60 |
| 6 | Reduce to ADT (Foreign) | 44: | | | 44 |

DILLON LOADOMETER STATION PASSENGER CARS (Cont.)

| | Origin | | Destination | | | |
|---|---|---|---|---|---|---|
| | | Possible Diversion | Inter County | Intra County | Foreign | |
| 2 PM to 10 PM | Missoula | 1 | 0.5 | 0.5 | | |
| | Great Falls | 1 | 1 | | | |
| | Other Towns | 27 | | 19 | 5 | 3 |
| | Counties | 10 | | 4 | 6 | |
| | California | 2 | 0.5 | | | 1.5 |
| M | Arizona | 1 | 0.5 | | | 0.5 |
| A | Other States | 8 | | | | 8 |
| R. | Total O. D. Sample | 50 | 2.5 | 23.5 | 11 | 13 |
| 31 | Expand to Actual Count (Local) | 238 | 9 | 143 | 67 | 19 |
| 1 | | | | | | |
| 9 | Expand to Actual Count (Foreign) | 31 | 3 | | | 28 |
| 3 | | | | | | |
| 7 | Reduce to ADT (Local) | 328 | 12 | 197 | 92 | 27 |
| | Reduce to ADT (Foreign) | 37 | 4 | | | 33 |
| | 6 AM - 10 PM Reduce to ADT (All traffic) | 606 | 37 | 243 | 162 | 164 |
| | (Local) | | | | | |
| | Estimated ADT 10PM-6AM | 64 | 3 | 26 | 18 | 17 |
| | (Foreign) | | | | | |
| | Estimated ADT 10PM-6AM | 6 | 1 | | | 5 |
| | 24 Hour Average Daily Traffic | 676 | 41 | 269 | 180 | 186 |

The data procured at the loadometer station south of Helena on US-91 substantiate these findings to some degree; it was found that there was a possible diversion of forty-four cars per day, ten of them foreign as against an estimated five at Dillon. The findings at Dillon were accepted as a basis for estimates of future traffic which might conceivably be diverted to the new route.

It is to be noted that this element of the study was conducted along what is believed to be conservative lines. For example, the local passenger car having origin in Outlook was allocated one-half to US-91 as is and one-half to the new route as a possible diversion, this for the reason that the driver might choose to see Butte and environs about half the time in preference to going over the new route. Similar reasoning prevailed as regards traffic originating in Dillon and bound for Helena and points north.

The sample, except as it related specifically to possible diversions, was considered to be significant of travel habits in respect to county lines and the state boundaries.

As to trucks, it was found that the sample was inadequate or lacking in true possibilities of diversion. Out of the hundreds of samples at loadometer stations at Helena and Dillon it was found that there were but two possibilities of diversion to the new route. Accordingly, truck traffic was diverted in about the same proportion as it exists in 1944 on US-91 out of Dillon, eight trucks per day, to round off the diversion at fifty units by throwing in another diverted passenger car. These figures were expanded by 30% to arrive at the 1960 traffic estimate. Those elements of truck traffic were broken down further to maintain the relationship between light, medium, and heavy truck traffic as it exists on US-91 out of Dillon on the Federal Aid System. The diversion data are tabulated hereinafter:

POSSIBLE DIVERSION TO THE WHITEHALL-BOULDER ROAD

| Vehicle Type | 1941 | + 30%: 1960 |
|---|---|---|
| Passenger Cars (Local) | 36 | 47 |
| Passenger Cars (Foreign) | 6 | 8 |
| Sub-Total Passenger Cars | 42 | 55 |
| Trucks, Light | 4.8 | 6.0 |
| Trucks, Medium | 0.5 | 0.6 |
| Trucks, Heavy | 0.1- | 0.1 |
| Trac. Tk. & Semi-Trailers | 2.5 | 3.1 |
| Truck & Full Trailer | 0.1- | 0.1 |
| Buses | 0.1- | 0.1 |
| Sub-Total, Trucks | 8.0 | 10.0 |
| TOTAL, ALL TRAFFIC | 50.0 | 65.0 |

These data are combined with the estimate of traffic density for 1960 for the Hill Road with results as follows:

ESTIMATED AVERAGE DAILY TRAFFIC FOR 1960

| Vehicle Type | Ave. Daily Traffic |
|---|---|
| Passenger Cars, Local | 192 |
| Passenger Cars, Foreign | 11 |
| Sub-Total, Passenger Cars | 203 |
| Trucks, Light | 31.9 |
| Trucks, Medium | 3.1 |
| Trucks, Heavy | 0.5 |
| Tractors, Trucks & Semi-Trailers | 16.5 |
| Trucks & Full Trailers | 0.5 |
| Buses | 0.5 |
| Sub-Total, Trucks | 53.0 |
| TOTAL ALL TRAFFIC | 256.0 |

3. Annual Revenues.

To arrive at an estimate of annual revenues the traffic data were resolved into vehicle miles and then into ton miles. These data were extended on the basis of unit net revenues per ton mile to arrive at an estimate of the total annual income. Unit net revenue rates derive from a general study conducted by this department. Average gross ton figures for each class of vehicle were also ascertained in course of the research work of the Planning Survey.

HIGHWAY PROJECT ANALYSIS

Traffic Income
1960

Location of project MONTANA Description of project Whitehall-Boulder County Jefferson

Highway _____ Highway System F.A.S. Length 27.0 Miles Date of Analysis November, 1945

| Traffic Type | Average Annual Traffic: Vehicles 1/ | Tons 2/ | Vehicle Miles 3/ | Ton Miles 4/ | Unit Net Revenues Per Ton Mile | Total Annual Net Revenue |
|---|---|---|---|---|---|---|
| Passenger Cars - Mont. | 70,080 | 105,120 | 1,892,160 | 2,838,240 | .002188 | $ 6,210 |
| Cars - Foreign | 4,015 | 6,022 | 72,270 | 162,594 | .001779 | 193 |
| Total Passenger Cars | 74,095 | 111,142 | 1,964,430 | 3,000,834 | | $ 6,403 |
| Trucks, Light | 11,643 | 38,073 | 314,364 | 1,027,971 | .003248 | $ 3,339 |
| Trucks, Medium | 1,131 | 7,781 | 30,537 | 210,087 | .002382 | 500 |
| Trucks, Heavy | 182 | 2,029 | 4,914 | 54,783 | .001619 | 88 |
| Trucks, Semi-Trailer | 6,022 | 89,667 | 162,594 | 2,421,009 | .001543 | 3,736 |
| Trucks, Full-Trailer | 183 | 4,165 | 4,941 | 112,455 | .001396 | 157 |
| Busses, School | | | | | | |
| Busses, Other | 183 | 1,647 | 4,941 | 44,469 | .001873 | 83 |
| Total Trucks & Busses | 19,344 | 143,362 | 522,291 | 3,870,774 | | $ 7,903 |
| Total all vehicles | 93,439 | 254,504 | 2,486,721 | 6,871,608 | | $14,306 |

Average weight of trucks 7.411 tons; All vehicles 2.72 tons. Total Annual Income...$14,306

Percentage truck traffic 20.7%.

Amortization period 20 years.

1/Average daily traffic as set forth in the preceding section multiplied by 365.

2/Column 1/ multiplied by average gross weights as set forth herebelow:

| | |
|---|---|
| Passenger Cars. . . . . at | 1.5 tons |
| Trucks, Light . . . . . at | 3.27 tons |
| Trucks, Medium . . . . at | 6.88 tons |
| Trucks, Heavy . . . . . at | 11.15 tons |
| Trucks & Semi-Trailers. at | 14.89 tons |
| Trucks & Full Trailers. at | 22.76 tons |
| Busses. . . . . at | 9.00 tons |

3/ Column 1/multiplied by 27, the length of the proposed improvement.

4/ Column 2/ multiplied by 27, the length in miles of the proposed improvement.

4. Time Element Savings.

Time element savings accrue to traffic as a result of surface and alignment improvements and because of shortened travel distance. In this particular case, the Boulder-Whitehall traffic will not be benefited by any great saving in travel distance, but the improvement in wearing surface and alignment will serve to increase the average travel speed. That traffic diverted from US-91 will be benefited by a saving of 17 miles on travel distance and an increased travel rate along the length of the route from Dillon to Boulder and vice versa. Composite time element savings are tabulated herebelow. The "New" speed rates originate with studies conducted by the Oregon Highway Department and coincide with the speeds recommended by Standard No. 1, (See Basic Design Categories). "Existing" speed rates are set in accord with Oregon standards modified by the writer's knowledge of conditions in the area of the proposed improvement and along US-91, Dillon to Boulder.

HIGHWAY PROJECT ANALYSIS Time Element Savings

Location of Project Montana County Jefferson
Description of Project Whitehall-Boulder
Highway number Highway System F.A. Secondary
Length 27.0 miles Date of analysis November, 1945

| Annual Traffic Volume | Boulder-Whitehall Traffic | | Diverted Traffic | |
|---|---|---|---|---|
| | New | Existing | New | PTW 1/ |
| Private Passenger cars(per year) | 54,020 | | 20,075 | |
| Trucks, light (per year)..... | 9,453 | | 2,190 | |
| Trucks, medium (per year)..... | 912 | | 219 | |
| Trucks, heavy (per year)..... | 5,312 | | 1,241 | |
| 2/Busses (per year)..... | | | | |
| Totals..... | 69,714 | | 23,725 | |
| **Private Passenger Cars** | | | | |
| Average speed (miles per hour). | 43 | 35 | 43 | 40 |
| Distance (Miles)..... | 27 | 27 | 84 | 101 |
| Time (hours per trip)..... | 0.628 | 0.771 | 1.953 | 2.525 |
| Time savings per vehicle..... | 0.143 | | 0.572 | |
| Value of savings($/vehicle-hour) | $0.60 | | $0.60 | |
| Annual traffic volume | 54,020 | | 20,075 | |
| Totals..... | $4,635 | | $6,890 | |

1/ PTW = Present Traveled Way. 2/Busses included with Trucks, heavy.

HIGHWAY PROJECT ANALYSIS Time Element Savings (Cont)

| Trucks, Light | Boulder-Whitehall Traffic | | Diverted Traffic | |
|---|---|---|---|---|
| | New | Existing | New | PTW 1/ |
| Average speed (miles per hour). | 39 | 30 | 39 | 35 |
| Distance (miles)..... | 27 | 27 | 84 | 101 |
| Time (hours per trip) | 0.692 | 0.900 | 2.154 | 2.886 |
| Time savings per vehicle..... | 0.203 | | 0.732 | |
| Value of savings($/vehicle-hour) | $0.86 | | $0.86 | |
| Annual traffic volume..... | 9,453 | | 9,453 | |
| Total..... | $ 1,691 | | $ 1,379 | |
| Trucks, Medium | | | | |
| Average speed (miles per hour). | 35 | 26 | 35 | 31 |
| Distance (miles)..... | 27 | 27 | 84 | 101 |
| Time (hours per trip)..... | 0.771 | 1.038 | 2.400 | 3.258 |
| Time savings per vehicle..... | 0.267 | | 0.858 | |
| Value of savings($/vehicle-hour) | $1.17 | | $1.17 | |
| Annual traffic volume..... | 912 | | 219 | |
| Total..... | $ 285 | | $ 220 | |
| Trucks, Heavy | | | | |
| Average speed (miles per hour). | 32 | 23 | 32 | 28 |
| Distance (miles)..... | 27 | 27 | 84 | 101 |
| Time (hours per trip)..... | 0.844 | 1.174 | 2.625 | 3.607 |
| Time savings per vehicle..... | 0.330 | | 0.982 | |
| Value of savings ($/vehicle-hour) | $1.47 | | $1.47 | |
| Annual traffic volume..... | 5,312 | | 1,241 | |
| Total..... | $ 2,585 | | $1,791 | |
| Total Each Class'n.... | $ 9,196 | | $ 10,280 | |
| TOTAL ANNUAL TIME ELEMENT SAVINGS ..... | | | $ 19,476 | |

1/ PTW = Present Traveled Way.

5. Mileage Element Savings.

These savings accrue to traffic as a circumstance of improved riding surface, decreased rise and fall, decreased gradient and improved alignment. These factors operate to decrease wear and tear on engines and tires; they make a gallon of gas stretch further. The estimated savings are tabulated hereinafter:

Mileage Element Savings

HIGHWAY PROJECT ANALYSIS

Location of project Montana County Jefferson
Description of Project Whitehall-Boulder
Highway number Highway system F.A. Secondary
Length 27.0 miles Date of Analysis November, 1945

| | Routes | | | |
|---|---|---|---|---|
| | Boulder-Whitehall Traffic | | Diverted Traffic | |
| | New | Existing | New | PTW |
| **Distance 1/** | | | | |
| Length (miles) | 27 | 27 | 84 | 101 |
| Distance saving (miles) | 0 | | 17 | |
| Average annual traffic (tons) | 197,297 | | 57,207 | |
| Annual traffic saving (ton-mi.) | | | 972,519 | |
| Cost ($/ton-mile) | | | 0.0195 | |
| Total | | | $ 18,964 | |
| **Surface 2/** | | | | |
| Roadway surface type | 2" Oil | Graded | Oil | Oil |
| Saving coefficient | 0.16 | | | |
| Aver. annual traffic (ton-mi.) | 5,327,019 | | | |
| Saving ($/ton-mile) | 0.00304 | | | |
| Total | $ 16,194 | | | |
| **Rise and Fall 3/** | | | | |
| Rise and fall (feet) | No | change | 3,220 | 5,150 |
| Saving (feet) | | | 1,930 | |
| Saving (foot-tons) | | | 110,409,510 | |
| Saving ($/foot-ton) | | | $4.26 x $10^{-6}$ | |
| Annual Saving | | | | |
| Total | | | $470 | |
| **Gradient 4/** | | | | |
| Gradients in per cent | No | change | 2.00 | 4.00 |
| Red'n in gradient | | | 2.00 | |
| Average An. traffic (ton-mi.) | | | 1,544,589 | |
| Saving ($/ton-mile) | | | $2.953 x $10^{-4}$ | |
| Total | | | $456 | |
| **Alignment 5/** | | | | |
| Curvature rating | 10 | 5 | 10 | 8 |
| Points improvement | 5 | | 2 | |
| Saving (point-ton-miles) | 26,635,095 | | 3,089,178 | |
| Saving ($/point-ton-mile) | $0.0001 | | $0.0001 | |
| Total | $ 2,664 | | $309 | |
| Total element each class'n | $ 18,858 | | $20,199 | |

TOTAL ANNUAL MILEAGE ELEMENT SAVINGS $ 39,057

1/ 483 - High type Bituminous Surfacing

1/ Distance saved cuts down the over-all vehicle operating costs. Technical Bulletin No. 7, Oregon State Highway Department lists certain operating costs per ton-mile for each of the several vehicle types and offers diagrams which allow one to arrive at a composite ton mile cost when the average gross weight in tons of the truck traffic is known. Average gross tonnage computation for that truck traffic which might be diverted to the proposed improvement are shown herewith:

$$\frac{\text{Annual traffic, trucks (tons)}}{\text{Annual traffic, trucks}} = \frac{27095}{3651} = 7.609 \text{ tons} = 15,218 \text{ pounds}$$

$$\frac{\text{Average Daily Traffic (trucks)}}{\text{Average Daily Traffic (all units)}} = \frac{10}{65} = 15.4\%$$

By reference to Figure 114 of the Technical Bulletin it is found that the average cost per ton mile of traffic in the proportions and weights given herebefore would be $0.0195.

2/ Technical Bulletin No. 7 sets forth a system whereby the benefits of surface type improvement may be computed. It is assumed that the coefficient of betterment is 0.16 since the improvement raises the coefficient from graded, 0.19, to oiled surface, 0.03. Computations in reference to the Boulder-Whitehall ton mile costs are as follows:-

$$\frac{\text{Annual Traffic, Trucks (tons)}}{\text{Annual Traffic (trucks)}} = \frac{116,267}{15,693} = 7.408 \text{ tons} = 14,816 \text{ pounds}$$

$$\frac{\text{Average Daily Traffic, trucks}}{\text{Average Daily Traffic, all units}} = \frac{43}{191} = 22.5\%$$

Operating costs per ton mile for traffic in these proportions and weights, as shown in Figure 114, Technical Bulletin No. 7 are $0.019. Multiplying 0.019 by 0.16 we have $0.00304 per ton mile.

3/ Rise and fall was computed on US-91 from Dillon to Boulder with elevation controls as follows:

DILLON - BOULDER VIA BUTTE

| | Elev. | + | - |
|---|---|---|---|
| Dillon | 5380 | | |
| | | | 380 |
| Navy Station | 5000 | | |
| | | 630 | |
| 5 Mi. North Melrose | 5630 | | |
| | | | 205 |
| Moose Creek | 5425 | | |
| | | 205 | |
| Moose Creek Hill | 5630 | | |
| | | | 230 |
| Divide | 5400 | | |
| | | 440 | |
| Feeley (Cont. Divide) | 5840 | | |
| | | | 500 |
| Nissler Jct. | 5340 | | |
| | | 160 | |
| Butte | 5500 | | |
| | | 900 | |
| Woodville (Cont. Divide) | 6400 | | |
| | | | 1500 |
| Boulder | 4900 | | |
| | | 2335 | 2815 |
| | | 5150 | |

DILLON - BOULDER VIA WHITEHALL

| | Elev. | + | - |
|---|---|---|---|
| Dillon | 5380 | | |
| | | | 1020 |
| Whitehall | 4360 | | |
| | | 1370 | |
| Crest | 5730 | | |
| | | | 830 |
| Boulder | 4900 | | |
| | | 1370 | 1850 |
| | | 3220 | |

It is assumed for purposes of this analysis that the improvement in rise and fall will be effective within the limits of the proposed improvement, the average gradient would then exist as 3.5. Truck fuel cost for 15,218 pound gross weight as shown on Figure 123 of the Technical Bulletin would be $\$7.00 \times 10^{-6}$. Passenger car costs on the same basis would be $\$3.72 \times 10^{-6}$. Combining the two traffic elements and extending we have an average saving of:

$$15.4\% \text{ at } \$7.00 \times 10^{-6} = 1.08 \times 10^{-6}$$
$$85.6\% \text{ at } \$3.72 \times 10^{-6} = \underline{3.18 \times 10^{-6}}$$
$$\$4.26 \times 10^{-6}$$

4/ It is assumed that diverted traffic will be benefited by a 2% decrease in gradient by taking the Dillon-Whitehall-Boulder route. By reference to Technical Bulletin No. 7 and Figure 124 therein we have basic data as follows:-

Saving for passenger cars, $\$1.29 \times 10^{-4} \times 2 = \$2.58 \times 10^{-4}$

Saving for trucks gross wt., 15,218 lbs. $= \$8.00 \times 10^{-4} - \$3.00 \times 10^{-4}$
$= \$5.00 \times 10^{-4}$

Combining and extending in the proportion manifest in the diverted traffic.

$$84.6 \times 2.58 \times 10^{-4} = 2.183 \times 10^{-4}$$
$$15.4 \times 5.00 \times 10^{-4} = \underline{.770 \times 10^{-4}}$$
$$2.953 \times 10^{-4}$$

5/ It is not contemplated that improvement of the Hill Road will effect a great improvement in alignment as such, it is reasonable to think, however, that increased sight distances, and a proper superelevation embodied in Standard No. 1 will make a five point alignment improvement for the Boulder-Whitehall traffic. By the same token, the diverted traffic will avoid the congestion in Butte, the crooked alignment in the vicinity of Moose Creek, Woodville Hill and Elk Park Canyon. In consideration of these factors this writer has assigned an alignment point improvement of 2 as an estimate on the conservative side. The point-ton-mile saving rate derives from the Technical Bulletin.

6. Traffic Benefits, Hill Road.

This tabulation involves an allocation of benefits, fuel functions and non-fuel functions, in accord with the proportions advanced by the

Oregon Highway Department.

Traffic Benefits

## HIGHWAY PROJECT ANALYSIS

Location of Project Montana County Jefferson
Description of project Whitehall-Boulder
Highway number Highway system F.A. Secondary
Length 27.0 miles Date of analysis November 1945

### Mileage Element Factors

| Item | | Fuel Function | | Non-fuel Function | |
|---|---|---|---|---|---|
| Distance savings | $18,964 | 38% | $7,206 | 62% | $ 11,758 |
| Roadway surface savings | 16,194 | 41% | 6,640 | 59% | 9,554 |
| Rise and fall savings | 470 | 100% | 470 | | |
| Gradient savings | 456 | 100% | 456 | | |
| Alignment savings | 2,973 | 50% | 1,486 | 50% | $ 1,487 |
| Total Mileage Savings | $39,057 | | $16,258 | | $ 22,799 |

### Time Element Factors

| Type of Traffic | Annual Value of Time Savings |
|---|---|
| Passenger cars | $ 11,525 |
| Trucks, light | 3,070 |
| Trucks, medium | 505 |
| Trucks, heavy | 4,376 |
| Busses | |
| Total Time Savings | $ 19,476 |

### Other Benefit Items

| Item | Value |
|---|---|
| | $ |
| | |
| | |
| | |
| | |

### Recapitulation of Annual Benefits

| | | | |
|---|---|---|---|
| Total Fuel Function Benefits | | | $ 16,258 |
| Non-fuel function benefits | (Mileage element factors | $ 22,799 | |
| | (Time element factors | 19,476 | |
| Total Non-fuel Function Benefits | | | $ 42,275 |
| TOTAL ANNUAL BENEFITS | | | $ 58,533 |

7. Derivation of Quotients.

Now to marshal such factual data as we have assembled heretofore:

HIGHWAY PROJECT ANALYSIS

Location of project Montana County Jefferson
Description of project Whitehall-Boulder
Highway number Highway System F.A. Secondary
Length 27.0 miles Date of analysis November 1945

$I_{ar}$ = $ 14,306 [1/] $K_1$ = 1.00

$C_a$ = $ 32,463 [2/] $K_2$ = 0.51

$B_n$ = $ 42,275 [3/] $K_3$ = 0.25

$B_f$ = $ 16,258 $K_2K_3$ = 0.15 x 0.25 = 0.13

$K_1C_a$ = $ 32,463 $1-K_2K_3$ = 1.00 - 0.13 = 0.87

4/ $Q_s = I_{ar}/K_1C_a$ = 14306/32463 = 0.44

5/ $Q_{Bn} = B_n/K_1C_a$ = 42275/32463 = 1.30

6/ $Q_{Bf} = B_f/K_1C_a$ = 16258/32463 = 0.50

7/ $Q'_s = Q_s - K_2K_3Q_{Bf}$ = 0.44 - 0.13 x 0.87 = 0.44 - 0.07 = 0.37

8/ $Q_c = 0.707\ (Q_s + Q_{Bn} + Q_{Bf}(1-K_2K_3))$ = 0.707 (0.44 + 1.30 + 0.50 x .87)
= 0.707 (0.44 + 1.30 + 0.44) = 0.707 x 2.18
= 1.54

1/ The constant $K_1$ represents the Pro Rata cost chargeable to Road User Funds, the Gasoline License Tax Levy in this case.

2/ The constant $K_2$ represents the proportion of the total fuel savings which derives from the diverted traffic. By reference to the tabulation of Mileage Element Savings we find that the fuel function benefits accruing to the diverted traffic are as follows:

| | |
|---|---|
| Distance Savings, 38% of $18,964 = | $7,206 |
| Rise & Fall savings, 100% of $470 = | 470 |
| Gradient Savings, 100% of $456 = | 456 |
| Alignment Savings, 50% of $309 = | 155 |
| TOTAL | $8,287 |

Dividing this value by the total value of the fuel function benefits, $16,258, we arrive at the constant value of $K_2$, 0.51.

3/ The constant $K_3$ represents the ratio of the fuel tax to the total cost of fuel (5/20).

4/ $Q_s$, the solvency quotient, shows that the route when built will "earn" 44% of its cost.

5/ & 6/ $Q_{Bn}$ and $Q_{Bf}$, representing non-fuel and fuel function benefits respectively, show that the monetary values of these benefits will exceed the capital costs by 30% in the first case and will equal half the capital costs in the second instance.

7/ $Q'_s$ represents a corrected solvency quotient. The immediate effect of diverting traffic to the routing will be to decrease revenues on US-91 - this quotient represents the solvency standing of the routing as it would be if we "kept books" on all the roads, primary and secondary, in the region.

8/ $Q_c$ represents the composite quotient of the routing when income and benefits in relation to costs are taken into consideration - it is the true measure of the worth of any proposed routing. It is feasible but not truly necessary to build a road when the composite quotient is unity - this, generally speaking, would indicate a situation where benefits would equal anticipated revenues. In other words, the benefits would operate to pay the revenues, in which case the existing roads would serve adequately. The composite quotient for the Hill Road is 1.54, a resultant which would eminently recommend construction of the route.

B. VALLEY ROAD, 33 MILES.

1. Annual Cost Calculations.

Drawing on the experience data set forth in the cost calculations

for the Hill Road we have estimated unit prices per mile as follows:-

Cardwell to Graded Portion of the Valley Road, 17.5 miles

| | |
|---|---|
| Grading..... | $3,500 |
| Assuming about 20% increase over 1940-1941 prices | |
| Gravel Base & Surface..... | $3,500 |
| Assuming quantities to be less than those on the Vigilante Trail but at a higher unit price. | |
| Clearing and Grubbing..... | $ 290 |
| Assuming prices to be same as for 1940 construction but effective for only three miles. | |
| Oil Surfacing..... | $1,300 |
| Assuming prices to be similar to those for the Vigilante Trail. | |
| Minor Drainage Structures..... | $2,000 |
| Assuming less need for such construction than was apparent in 1940-1941. | |
| Major Structures..... | $ 500 |
| Assuming conditions similar to the 1940 construction. | |
| Engineering..... | $1,000 |
| Assuming conditions analagous to the 1940 construction. | |
| Right of Way..... | $ 250 |
| Assuming conditions similar to the Vigilante Trail but in lesser areal dimension. | |
| Sub-Total.. | $12,340 |
| + 10% for contingencies.. | 1,234 |
| Total Cost for New Construction.. | $13,574 |

Gravel Base, Gravel Surfacing and Oiling, 15.5 miles

| | |
|---|---|
| Gravel Base & Surface..... | $4,000 |
| Assuming costs to be in excess of those manifest on the proposed new construction by reason of probable shouldering operations and other restoration activities. | |
| Oil Surfacing..... | $1,300 |
| Assuming prices to be similar to those for the Vigilante Trail. | |
| Engineering..... | $ 300 |
| Assuming a greatly decreased cost for engineering there being only gravel surfacing and oiling to administer. | |
| Sub-Total..... | $5,600 |
| + 10% for contingencies..... | 560 |
| Total Cost for Gravel and Oil Surfacing..... | $6,160 |

Drawing on these data we find the cost of the new construction, 17.5 miles, to be 17.5 x $13,574..... $237,545

The cost of the gravel surfacing and the oiling will be,

15.5 x $6,160..... $ 95,480

to render the total cost of new construction at..... $333,025

To the total for the new construction it is necessary to add the 1940-1941 costs for grading and installation of minor drainage structures on the Valley Road, these being $114,509. Assuming we were to capitalize the route as of 1944 the total cost would be $447,534 ($333,025 + $114,509). Following the same procedure as for the Hill Road - assigning interest at 2½% to be amortized in 20 years - we find the annual capital costs of construction to be $28,687.

As for probable maintenance costs, it is believed that this item will be less per mile than the Hill Road - for purposes of this analysis this figure was set at $200 per mile.

The total annual costs are recapitulated on the "Annual Cost Calculations" sheet which follows:

ANNUAL COST CALCULATIONS

Location of project Montana County Jefferson

Description of project Cardwell-Boulder

Highway number _____ Highway system F.A. Secondary

Length 33.0 miles Date of analysis November 1945

CAPITAL COSTS

| Item | Net Cost | Gross Cost 1/ | Amort. Period | Annual Capital Cost |
|---|---|---|---|---|
| Rights of way, Easements, etc. | $ 4,375 | $ | | $ |
| Clearing, grading, etc. | 124,676 | | | |
| Pavements and surfacing: | | | | |
| Type Gravel | 123,250 | | | |
| Type Oil | 42,900 | | | |
| Structures: | | | | |
| Type Minor | 74,743 | | | |
| Type Major | 12,282 | | | |
| Other Construction items:... | 65,308 | | | |
| Unamortized cost const..... | $447,534 | 20 yrs. | At 2½% | |
| 1. Total annual capital cost..... | | | | $ 28,687 |

MAINTENANCE COSTS

| | |
|---|---|
| 2. Total annual maintenance cost 33 miles @ $200 | $ 6,600 |
| TOTAL ANNUAL COSTS (1 + 2) | $ 35,287 |

1/ Engineering and 10% for contingencies included with "Other Construction Items".

2. Average Daily Traffic, 1960.

Average Daily Traffic in 1941 for the Boulder-Cardwell road was found to be 27 local passenger cars, 1 foreign car, and 15 trucks. It is possible that some traffic will be diverted from the Hill Road; the measure of such diversion is difficult to ascertain from the records at hand. The writer assumed that one-fourth of the present passenger car traffic between Whitehall and Boulder would use the Hill Road half the time and the Valley Road half the time to make an effective passenger car diversion of ten cars per day. It was further assumed that half of the truck traffic might use the Valley Road when loaded and the Hill Road when empty to make an effective diversion of five units per day. Possible diversion from US-91, Dillon to Boulder, would be the same as that set forth in the discussion of the Hill Road. Estimated traffic figures for the Valley Road in 1960 are shown herewith:

TRAFFIC DATA VALLEY ROAD

| Category and Traffic Type | 1941 | + 50% Compl. Const. | + 30% 1960 |
|---|---|---|---|
| Boulder-Cardwell | | | |
| Pass. Cars, Local | 27 | 41 | 53 |
| Pass. Cars, Foreign | 1 | 1 | 2 |
| Trucks | 15 | 23 | 30 |
| Boulder-Whitehall | | | |
| Pass. Cars, Local | 10 | 15 | 20 |
| Pass. Cars, Foreign | | | |
| Trucks | 5 | 7 | 10 |
| Dillon-Boulder Diversion | | | |
| Pass. Cars, Local | 36 | | 47 |
| Pass. Cars, Foreign | 6 | | 8 |
| Trucks | 8 | | 10 |
| All Traffic | | | |
| Pass. Cars, Local | | | 120 |
| Pass. Cars, Foreign | | | 10 |
| Trucks | | | 50 |
| All Vehicles | | | 180 |

3. Annual Revenues.

The traffic data were then resolved into ton miles per year and multiplied by known ton mile income factors to establish revenues as follows:

HIGHWAY PROJECT ANALYSIS — Traffic Income 1960

Location of project MONTANA Description of project Cardwell-Boulder County Jefferson
Highway ____ Highway System F.A.S. Length 33 miles Date of analysis November 1945

| Traffic Type | Average Annual Traffic: Vehicles 1/ | Tons 2/ | Vehicle Miles 3/ | Ton Miles 4/ | Unit Net Revenues: Per Ton Mile | Total Annual Net Revenue |
|---|---|---|---|---|---|---|
| Passenger Cars-Montana | 43,800 | 65,701 | 1,445,400 | 2,168,133 | .002188 | $ 4,744 |
| " Cars-Foreign | 3,650 | 5,474 | 120,450 | 180,642 | .001779 | 321 |
| Total passenger cars | 47,450 | 71,175 | 1,565,850 | 2,348,775 | | 5,065 |
| Trucks, light | 10,986 | 35,924 | 362,538 | 1,185,492 | .003248 | 3,850 |
| Trucks, medium | 1,059 | 7,286 | 34,947 | 240,438 | .002382 | 573 |
| Trucks, heavy | 183 | 2,040 | 6,039 | 67,320 | .001619 | 109 |
| Trucks, semi-trailer | 5,657 | 84,232 | 186,681 | 2,779,656 | .001543 | 4,289 |
| Trucks, full-trailer | 183 | 4,165 | 6,039 | 137,445 | .001396 | 192 |
| Busses, school | | | | | | |
| Busses, other | 183 | 1,647 | 6,039 | 54,351 | .001873 | 102 |
| Total trucks & busses | 18,251 | 135,294 | 602,283 | 4,464,702 | | 9,115 |
| Total all vehicles | 65,701 | 206,469 | 2,168,133 | 6,813,477 | | |

Average weight of trucks 7.413 tons; All vehicles 3.14 tons. Total Annaul Income. $14,180

Percentage truck traffic 27.8%.

Amortization period 20 years.

1/ Average daily traffic multiplied by 365.
2/ Column 1/multiplied by average gross weights (see discussion Hill Road).
3/ Column 1/multiplied by 33, the length of the project in miles.
4/ Column 2/multiplied by 33, the length of the project in miles.

4. Time Element Savings.

Dillon-Boulder traffic when diverted to this road will save four miles in travel distance. Due to a more favorable gradient the "new" speeds for the trucks have been increased by one mile over that shown in the tabulation for the Hill Road.

HIGHWAY PROJECT ANALYSIS

Time Element Savings

Location of project Montana County Jefferson
Description of project Cardwell - Boulder
Highway number Highway System F.A. Secondary
Length 33 miles Date of analysis November 1945

| | Cardwell-Boulder Traffic | | Diverted Traffic | |
|---|---|---|---|---|
| Annual Traffic Volume | New | Existing | New | PTW |
| Private Passenger cars(per year) | 27,375 | | 20,075 | |
| Trucks, light (per year)..... | 8,796 | | 2,190 | |
| Trucks, medium (per year)..... | 840 | | 219 | |
| Trucks, heavy (per year)..... | 4,964 | | 1,242 | |
| Totals..... | 41,975 | | 23,726 | |
| Private Passenger Cars | | | | |
| Average speed (miles per hour). | 43 | 35 | 43 | 40 |
| Distance (Miles)..... | 33 | 33 | 97 | 101 |
| Time (hours per trip)..... | 0.767 | 0.943 | 2.256 | 2.525 |
| Time savings per vehicle..... | 0.176 | | 0.269 | |
| Value of savings($/vehicle-hour) | $0.60 | | $0.60 | |
| Annual traffic volume..... | 27,375 | | 20,075 | |
| Total..... | $2,891 | | $3,240 | |
| Trucks, Light | | | | |
| Average speed (miles per hour). | 39 | 30 | 39 | 35 |
| Distance (miles)..... | 33 | 33 | 97 | 101 |
| Time (hours per trip)..... | 0.846 | 1.100 | 2.487 | 2.886 |
| Time savings per vehicle..... | 0.254 | | 0.399 | |
| Value of savings ($/vehicle-hour) | $0.86 | | $0.86 | |
| Annual traffic volume..... | 8,796 | | 2,190 | |
| Total..... | $1,921 | | $751 | |
| Trucks, Medium | | | | |
| Average speed (miles per hour). | 36 | 26 | 36 | 31 |
| Distance (miles)..... | 33 | 33 | 97 | 101 |
| Time (hours per trip)..... | 0.917 | 1.269 | 2.694 | 3.258 |
| Time savings per vehicle..... | 0.352 | | 0.564 | |
| Value of savings($/vehicle-hour) | $1.17 | | $1.17 | |
| Annual traffic volume..... | 840 | | 219 | |
| Total..... | $346 | | $145 | |

HIGHWAY PROJECT ANALYSIS Time Element Savings (Cont)

| Trucks, Heavy | Cardwell-Boulder Traffic New | Cardwell-Boulder Traffic Existing | Diverted Traffic New | Diverted Traffic PTW |
|---|---|---|---|---|
| Average speed (miles per hour. | 33 | 23 | 33 | 28 |
| Distance (miles)..... | 33 | 33 | 97 | 101 |
| Time (hours per trip)..... | 1.000 | 1.435 | 2.939 | 3.607 |
| Time savings per vehicle..... | 0.435 | | 0.668 | |
| Value of savings($/vehicle-hour) | $1.47 | | $1.47 | |
| Annual traffic volume..... | 4,964 | | 1,241 | |
| Total..... | $3,174 | | $1,219 | |
| Total Each Class'n. | $8,332 | | $5,355 | |

TOTAL ANNUAL TIME ELEMENT SAVINGS ..... $13,687

5. Mileage Element Savings.

Refer to similar discussion for the Hill Road.

HIGHWAY PROJECT ANALYSIS Mileage Element Savings

Location of project Montana County Jefferson
Description of project Cardwell - Boulder
Highway number Highway system F. A. Secondary
Length 33 miles Date of Analysis November 1945

| | Routes Cardwell-Boulder Traffic New | Cardwell-Boulder Traffic Existing | Diverted Traffic New | Diverted Traffic PTW |
|---|---|---|---|---|
| Distance 1/ | | | | |
| Length (miles)..... | 33 | 33 | 97 | 101 |
| Distance saving (miles)..... | 0 | | 4 | |
| Average annual traffic (tons)... | | | 57,207 | |
| Annual traffic saving (ton-mi.). | | | 228,828 | |
| Cost ($/ton-mile)..... | | | 0.0195 | |
| Total..... | | | $4,462 | |
| Surface 2/ | | | | |
| Roadway surface type..... | Oiled | Graded | Oiled | Oiled |
| Saving coefficient..... | 0.16 | | | |
| Aver. annual traffic (ton-mi.). | 4,925,646 | | | |
| Saving ($/ton-mile)..... | 0.00288 | | | |
| Total..... | $14,186 | | | |
| Rise and Fall 3/ | | | | |
| Rise and fall (feet)..... | No change | | 1,730 | 5,150 |
| Saving (feet)..... | | | 3,420 | |
| Saving (foot-tons)..... | | | 195,647,940 | |
| Saving ($/foot-ton)..... | | | $4.33 x $10^{-6}$ | |
| Total..... | | | $847 | |

Mileage Element Savings (Cont.)

HIGHWAY PROJECT ANALYSIS

| | Cardwell-Boulder Traffic | | Diverted Traffic | |
|---|---|---|---|---|
| | New | Existing | New | PTW |
| Gradient 4/ | | | | |
| Gradients in percent..... | No Change | | 1.00 | 4.00 |
| Red'n in gradient..... | | | 3.00 | |
| Average An. traffic (ton-Mi.) | | | 1,887,831 | |
| Saving ($/ton-mile)..... | | | $4.87 x $10^{-4}$ | |
| Total..... | | | $919 | |
| Alignment 5/ | | | | |
| Curvature rating..... | 10 | 7 | 10 | 8 |
| Points improvement..... | 3 | | 2 | |
| Saving (point-ton-miles)..... | 14,776,938 | | 3,775,662 | |
| Saving ($/point-ton-mile).... | $0.0001 | | $0.0001 | |
| Total..... | $1,478 | | $378 | |
| Total each class'n.. | $15,664 | | $6,606 | |

TOTAL ANNUAL MILEAGE ELEMENT SAVINGS $ 22,270

1/ See note 1/, mileage element savings, for the Hill Road.

2/ See note 2/, mileage element savings, for the Hill Road, for derivation of the coefficient of betterment.

Computations in reference to the Boulder-Cardwell ton-mile costs are as follows:-

$$\frac{\text{Annual Traffic Trucks, tons}}{\text{Annual Traffic Trucks, units}} = \frac{108,199}{14,600} = 7.441 \text{ tons} = 14.822 \text{ pounds}$$

$$\frac{\text{Average Daily Traffic, trucks}}{\text{Average Daily Traffic, all units}} = \frac{40}{115} = 34.8\%$$

Operating costs per ton mile for traffic in these proportions would be as follows:-

Passenger Cars, 65.2% = 0.652 x 2.07 = 1.35
Trucks, 34.8% = 0.348 x 1.30 = 0.45
Combined Cost = 1.80

1,80 x 0.16 = 0.00288

3/ In reference to the diverted traffic; it is assumed that the existing gradient along a significant length of US-91 is 4.0%. Truck fuel costs for 15,218 pound gross weight as shown in figure 123 would be $7.50

per foot-ton x $10^{-6}$. Combining the two traffic elements, we average foot-ton-dollar-saving as follows:=

15.4% at \$7.50 x $10^{-6}$ = 1.15 x $10^{-6}$

84.6% at \$3.72 x $10^{-6}$ = 3.10 x $10^{-6}$

All Traffic =\$4.33 x $10^{-6}$

4/ It is assumed that there is an effective decrease of 3% in the gradient and that the new grade will be 2%. By reference to Figure 114, Technical Bulletin No. 7 we have basic data as follows:

Saving for passenger cars \$1.29 x $10^{-4}$ x 3 = \$3.87 x $10^{-4}$

Saving for trucks, gross wt., 15,218, = \$13.00 x $10^{-4}$ - \$3.00 x $10^{-4}$
= \$10.00 x $10^{-4}$

Combining and extending in the proportions manifest in the diverted traffic:

84.6 x 3.87 x $10^{-4}$ = 3.27 x $10^{-4}$
15.4 x 10.00 x $10^{-4}$ = 1.54 x $10^{-4}$
Combined Cost = 4.81 x $10^{-4}$

5/ See discussion of alignment point savings for the Hill Road.

6. Traffic Benefits, Valley Road.

This tabulation involves an allocation of benefits, fuel functions and non-fuel functions in accord with the proportions advanced by the Oregon Highway Department.

Traffic Benefits

# HIGHWAY PROJECT ANALYSIS

Location of project Montana County Jefferson
Description of project Cardwell - Boulder
Highway number Highway system F.A. Secondary
Length 33.0 miles Date of analysis November 1945

## Mileage Element Factors

| Item | | Fuel Function | | Non-fuel Function | |
|---|---|---|---|---|---|
| Distance savings | $ 4,462 | 38% | $1,696 | 62% | $2,766 |
| Roadway surface savings | 14,186 | 41% | 5,816 | 59% | 8,370 |
| Rise and fall savings | 847 | 100% | 847 | | |
| Gradient savings | 919 | 100% | 919 | | |
| Alignment savings | 1,856 | 50% | 928 | 50% | 928 |
| Total Mileage Savings | $22,270 | | $10,206 | | $12,064 |

## Time Element Factors

| Type of Traffic | Annual Value of Time Savings |
|---|---|
| Passenger cars | $ 6,131 |
| Trucks, light | 2,672 |
| Trucks, medium | 491 |
| Trucks, heavy | 4,393 |
| 1/ Busses | |
| Total Time Savings | $ 13,687 |

## Other Benefit Items

| Item | Value |
|---|---|
| | $ |
| | |
| | |
| | |
| | |

## Recapitulation of Annual Benefits

| | | | |
|---|---|---|---|
| Total Fuel Function Benefits | | | $ 10,206 |
| Non-fuel function benefits | (Mileage element factors | $ 12,064 | |
| | (Time element factors | 13,687 | |
| Total Non-fuel Function Benefits | | | $ 25,751 |
| TOTAL ANNUAL BENEFITS | | | $ 35,957 |

1/ Busses included with heavy trucks.

7. Derivation of Quotients.

Now to summarize the effects of each of the several elements discussed hereinbefore:

HIGHWAY PROJECT ANALYSIS

Location of project Montana . County Jefferson
Description of project Cardwell - Boulder
Highway number ____ Highway system F.A. Secondary
Length 33.0 miles Date of analysis November 1945

$I_{ar}$ = $14,180 [1/] $K_1$ = 1.00

$C_a$ = $35,287 [2/] $K_2$ = 0.36

$B_n$ = $25,751 [3/] $K_3$ = 0.25

$B_f$ = $10,206 $K_2K_3$ = 0.09

$K_1C_a$ = $35,287 $1-K_2K_3$ = 1.00 - 0.09

4/ $Q_s = I_{ar}/K_1C_a$ = 14180/35287 = 0.40

5/ $Q_{Bn} = B_n/K_1C_a$ = 25751/35287 = 0.73

5/ $Q_{Bf} = B_f/K_1C_a$ = 10206/35287 = 0.29

6/ $Q'_s = Q_s - K_2K_3Q_{Bf}$ = 0.40 - 0.03 = 0.37

7/ $Q_c = 0.707 (Q_s + Q_{Bn} + Q_{Bf}(1-K_2K_3))$ = 0.707 (0.40 + 0.73 + 0.29 x 0.91)
= 0.707 (0.40 + 0.73 + 0.26) = 0.707 x 1.39
= 0.98

1/ See similar discussion, Derivation of Quotients for the Hill Road.

2/ See similar discussion, Derivation of Quotients for the Hill Road. By reference to the tabulation of Mileage Element Savings we find that the fuel function benefits accruing to the diverted traffic are as follows:

| | | | |
|---|---|---|---|
| Distance Savings, | 38% of | $4,462 = | $1,696 |
| Rise & Fall Savings, | 100% of | 847 = | 847 |
| Gradient Savings, | 100% of | 919 = | 919 |
| Alignment Savings, | 50% of | 378 = | 189 |
| | TOTAL | | $3,651 |

3/ See similar discussion, Derivation of Quotients, for the Hill Road.

4/ $Q_s$, the solvency quotient, shows that the road when built will earn 40% of its cost.

5/ $Q_{Bn}$ and $Q_{Bf}$, the benefit quotients, show that the non-fuel benefits will be 73% of the capital costs and that the fuel benefits will be 29% of the capital costs.

6/ See discussion, Derivation of Quotients, for the Hill Road.

7/ This quotient, being less than unity, would indicate that the Valley Road is not a feasible or desirable road to be improved under the provisions of the Federal Aid Secondary program.

V. REMARKS

Attention is called to the fact that the comparison of the two routes, Boulder to Whitehall and Boulder to Cardwell, by use of the Oregon formula does not take into account the distance between Whitehall and Cardwell, a distance of approximately seven miles. If this had been taken into consideration more weight would have been given to the Hill Route as the major part of the traffic using either route is bound for Whitehall, or points south or west thereof. That is, the benefits and resulting solvency quotients on the Hill Route would be much higher than shown by the analysis.

It should be noted also that construction costs as shown herein are based on Federal Aid Secondary standards consequently; if the route should ever be placed on the Primary System as a through route to Dillon standards and construction costs would be increased considerably. However, this would have little or no effect on the selection of the route between Boulder and Whitehall.

Prepared and submitted by:
THE MONTANA HIGHWAY PLANNING SURVEY
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